Comparison of Fourth-harmonic and Combined Doubler/Subharmonic Mixer with integrated MMIC based Local Oscillator

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Abstract— **In this paper a comparison between a fourth harmonic mixer and a combined doubler/subharmonic mixer based on Schottky diodes working at 300 GHz with MMIC Local Oscillator (LO) integrated in a single enclosing is presented. Both configurations allow reducing the LO requirements, since a lower LO frequency is used. In addition, the integration of the MMIC Local Oscillator with the mixer in the same single metallic block is the main novelty and advantage of this work. Since only one block is used, flange connections are avoided. This way, misalignment errors are also prevented. Besides this advantage, the compactness of this solution is also remarkable, leading to a significant weight reduction.**

I. INTRODUCTION

FOR future THz applications new compact, flexible and portable receivers and transmitters are needed. Overall, for the development of Beyond 5G next generation mobile communication systems networks, where the THz signal sources must be not only compact, which implies reduced cost, but also operate at room temperature and have the potential for integration [1]. All these characteristics can be achieved including novel schemes [2-3].

In this work two 300 GHz receiver configurations will be compared. On the one hand, a fourth harmonic mixer [4], which is chosen because it is easier to find a local oscillator at W-Band (around 75 GHz) with enough power to pump the mixer diodes than at higher frequencies, as it would be the case of a subharmonic mixer. In addition, the LO can be based on COST MMICS and built on planar technology. Therefore, using planar technology for both designs, i.e. the mixer and the local oscillator, allows their integration in the same housing metallic block. On the other hand, a combined frequency doubler-subharmonic mixer based on Schottky diodes and using also a 75 GHz MMIC based Local Oscillator is developed. This solution integrates in the same substrate the doubler and the mixer, which share the same metallic packaging with the Local Oscillator. This way, the performance in terms of frequency conversion is similar to that of a forth harmonic mixer.

II. SUBHARMONIC MIXERS DESIGN

A 3D perspective view of both subharmonic mixers is shown in Fig.1. The local oscillator (LO) is the same for both devices. It is based on a commercial transmitter for automotive radar composed of TriQuint flip-chip components and a PLL that controls the output frequency. The output power is around 10 dBm.

On the other hand, both mixer prototypes are designed around an antiparallel pair of flip-chips Schottky diodes from UMS Foundry, while the frequency doubler circuit of the combined doubler/mixer is based on the antiseries configuration. The electrical characteristics for each diode are: ideality factor η = 1.2, saturation current Isat = 2e-16 A, resistance Rs = 7.3 Ω and junction capacitance Cj = 5.3 fF. The substrate is 100µm thick Cyclic Olefin Copolymer (COC) (εr = 2.3 and tanδ = 0.0009) [5].

Both configurations have been evaluated using a software combination of HFSS for the passive behaviour, e.g. filters, waveguide to microstrip transition, DC-Blocks… and ADS for non-linear analysis, e.g. Load-Pull for optimum diode embedding impedance calculation, conversion loss, noise temperature… For the combined doubler/mixer, the interaction between both circuits is also taken into account.

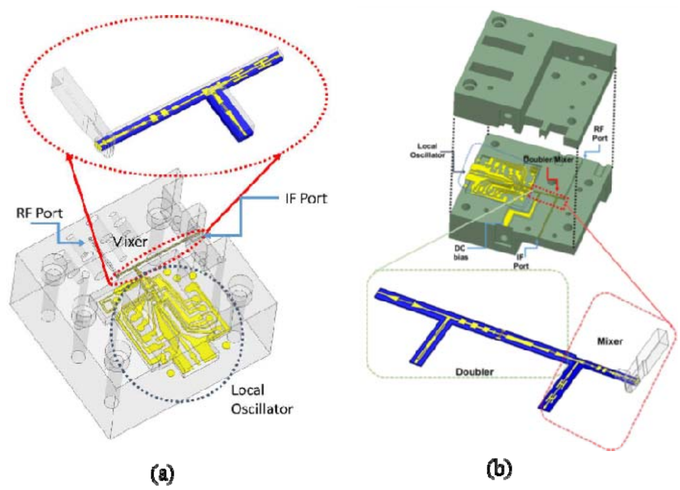

Fig. 1. 3D perspective view of the subharmonic mixers. (a) Fourth harmonic mixer prototype with local oscillator integrated in same metallic block and zoom on the mixer model for simulation. (b) Combined doubler/subharmonic mixer prototype with local oscillator in same metallic block and zoom on the doubler/mixer circuit.

III. RESULTS

Finally, both circuits have been fabricated and measured. The fabrication of the aluminum block has been realized in an external workshop by means of CNC machining. The mixer and local oscillator have been fabrication by means of a standard photolithography process at the ePublic University of Navarra's facilities. Pictures of the prototypes with zoom on the Schottky diodes can be seen in Fig.2.

The characterization has been realized by means of the Y-Factor technique using room temperature for the hot load and cooling the absorber material with liquid nitrogen for the cold load. The IF frequency is fixed to 2 GHz, then the LO is swept from 74 to 77 Ghz.

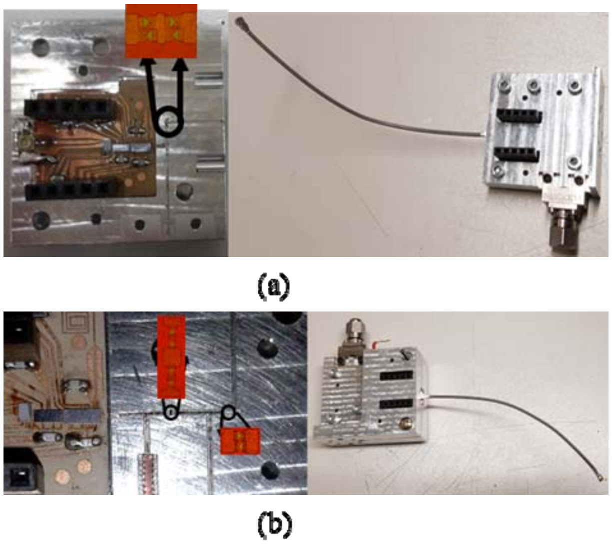

Fig. 2. Pictures of the fabricated harmonic mixers. (a) Fourth harmonic mixer prototype with local oscillator (left) and metallic block (rigth). (b) Combined doubler/subharmonic mixer prototype with local oscillator (left) and the enclosing metallic block (rigth).

Fig.3 shows the comparison between simulations and measurements between the fourth harmonic and the combined doubler/subharmonic mixer.

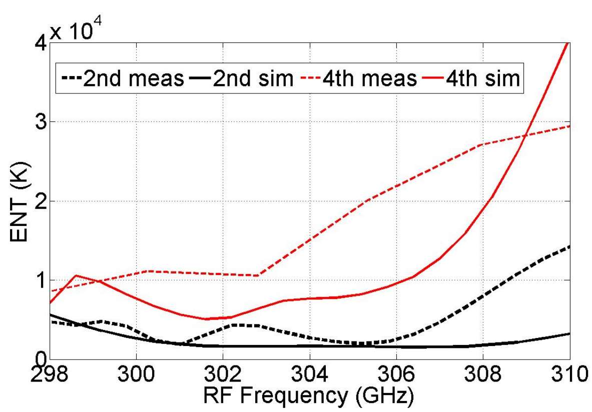

Fig. 3. Comparison between fourth harmonic mixer and combined doubler/subharmonic mixer. (Dashed black line) shows the measured performance of the combined doubler/subharmonic mixer. (Solid black line) shows the predicted response in simulation of the combined doubler/subharmonic mixer. (Dashed red line) shows the characterized fourth harmonic mixer and (Solid red line) the predicted performance of the fourth harmonic mixer.

The fourth harmonic mixer prototype yields a simulated and measured mean DSB equivalent noise temperature of 9000 Kand 17200 K, respectively. The combined doubler/mixer prototype yields a simulated and measured mean DSB equivalent noise temperature of 1900 K and 4800 K, respectively. There is a difference between the simulated and the measured performance, ascribed to the fact that the mixer is being underpumped, since the LO power cannot be neither controlled nor monitored. Besides, the tolerance errors due to manufacturing process and the fact that the diodes are welded also contribute to have higher losses. Nonetheless, the performance of the circuits presented in this work are not far from the state-of-the-art [4-5].

IV. Summary

Two different fourth harmonic mixer based on Schottky diodes integrated along with the local oscillator in the same metallic block are presented in this paper. One of them is a standard fourth harmonic mixer and the other one is a combined doubler/mixer so that the actual performance is more similar to a subharmonic mixer. The performance of both circuits is slightly worse than the state of the art. However, the additional losses and noise temperature compared are compensated with the compactness of the proposed solution.

V. Acknoledgement

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